Design and Test of a Suction Gas Producer Pressure Regulator

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1907

DESIGN AND TEST OF A

SUCTION GAS PRODUCER PRESSURE REGULATOR

A THESIS

PRESENTED BY

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MECHANICAL ENGINEERING

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I N D E X .

Power Plant, Cole Mfg. , Co. 60 H.P. Suction Gas Engine and Producer.

THESIS

OUTLINE OF WORK FOR THESIS.

Reading	Gas Engines, Producer Gas Engines. (Gas Producers, Suction Producers. (Gases, Producer Gas, Blast Furnace Gas.
Designing	(Suction Regulator, Various forms of Regulators (Combinations of Valves.
Experimenting	(Operating Engine and Producer under varying loads, with and without regulators. (Determining best size of regulator for a given engine. (Analysis of Gases. Heating value of coal and ash.

Consult:-

All current engineering literature.

Compile:-

Bibliographies of Literature. Producer Gas Engine.
Tests. Analysis of Gases.

As will be seen from the above outline, our thesis work consisted in getting a regulator, if possible, that would regulate the suction in a suction producer plant, in such a manner as to give a continuous draft through the producer, instead of the heavy pulls at irregular intervals attendent in most suction producers at the present day.

Perhaps in the first place it would be best to give a description of a suction gas producer in general; the origin of its construction; and, since our work was carried on in connection with the OTTO producer and

engine, a description of that producer in particular. In order to do this we quote from the "ELECTRICIAN" of April 7, 1905, Vol.54, Page 1006, and from the "ENGINEER" of June 15, 1904.

"The suction gas producer was brought about through the disadvantages encountered in the pressure plants. "All producer plants have one disadvantage----they require power to produce the blast necessary to force the air and steam through the system, and they require storage for the gas unless the requirements are perfectly uniform, which is never the case when the gas is used for power purposes. They require also a separate steam supply, and experiments have proved that when best results are obtained about 16% of the total fuel used is comsumed to generate this steam. Another disadvantage of this form of producer is that the gas being under pressure there is a liability to leakage, and as the gas has no smell and is of a highly poisonous character, serious accidents have happened, and pressure plants are quite unsuited to confined places."

"In 1888, M.Benier, a Frenchman, conceived the idea that these disadvantages might be overcome by arranging a closed producer in such a way that the air might be sucked through the producer by a suitable pump, instead of being forced into it by means of the steam jet, and that the gas thus aspirated might be delivered stroke by stroke to the engine as and when generated, and thus do away with the necessity of a gas holder. Also that the aspiration of the

pump would produce a slight vacuum in the producer and scrubber, and thus the waste heat could be utilized in an open boiler to generate the steam necessary to be mixed with the incoming air, so as to enrich the gas with the necessary hydrogen. In continuing his experiments, Benier himself found that a separate pump was unnecessary, as the suction of the piston of the engine in its upward stroke was sufficient to draw the gas through the system. Up to 1901 this form of producer was scarcely used in this country, partly on account of the general cheapness of gas, but principally in consequence of certain defects which were common to all the existing forms. The correct regulation of the steam to the air supply, and the control of the fire while the producer was in operation were not provided for; while the exact proportions between the area of the fire and heating surface of the boiler, the relations of these to each other, the temperature of the furnace, and the relation of the whole,to the size and speed of the engine were not understood. Now, however, these difficulties have been overcome, and a large unit has been run for weeks continuously night and day with a regularity quite equal to the very best steam plant."

"The advantages of these plants may be summarized as follows : Reasonable in cost, cheap and regular gas, perfectly safe from explosion, occupy small space, simple in design, and when in operation no moving parts, not liable to get out of order and simple to repair, easily put into operation and entirely automatic in action, require little attention, can be attended by unskilled labor, create no

nuisance even in confined places, no escape of poisonous gas possible, gas production stops the minute the engine stops always ready for starting, as the fire may be kept without relighting for six months at a time, requires no gas holder, applicable to all forms of gas engines, can be made regenera tive when necessary."

"The term "Suction Producer Gas Power" is descriptive. The system "produces" gas from the coal fed into the "Producer" or "Generator" and this gas is utilized in the gas engine in the same manner as illuminating gas or gasoline is used in theordinary gas or gasoline engine."

The Otto Suction Gas Producer.

From "The Engineer" of June 15, 1904.

"The Otto suction gas producer , in connection with the Otto engine, comes near to solving the problem of obtaining an economical power plant requiring the least attention and occupying the smallest amount of floor space. This producer has been developed from the well know pressure gas, or semi-water gas producer, in which fuel gas is generated and kept under pressure by forcing steam through a bed of incandescent coal. It differs from the older method in not requiring a costly steam boiler or large and expensive gas holder, and in having the apparatus arranged so that the gas generated is always under less than atmospheric pressure, thus rendering the escape of gas into the room impossible."

"The partial vacuum created in the engine is used to draw the air and steam necessary for generating

the gas through the producer, in quanities required and regulated by the power developed. The plant consists in the main of the producer, scrubber, vaporizer, expansion tank, and the engine."

"The generator forms a cylindrical iron shell lined with fire brick, and is provided below with a fire grate. The cover consists of a head piece carrying the coal hopper, on which latter are mounted the charging lid and closing device for the hood valve."

"The scrubber is a cylindrical tank, filled with coke, on top of which a spray of water is fed. In large plants, or where an extensive purification is desired, a second or dry scrubber is installed."

"The vaporizer in the large sizes consists of a rectangular tank placed between the producer and scrubber. The hot gases coming from the producer flow around vertical tubes containing water. The gases impart heat to the water and the resulting steam is led by suitable pipes under the fire grates in the producer. In the bottom half of the vaporizer is a second set of tubes connected on the one side by a suitable pipe with the atmosphere and on the other side with the producer below the grates. The air in passing through the vaporizer takes up heat from the gases thus causing a direct saving of the sensible heat of the gases which would otherwise be lost in the scrubber."

"In the smaller sizes the vaporizer is in the shape of a pan forming the top of the producer, and receives its heat from the hot gases leaving the fuel bed

immediately below. A water supply pipe and an overflow pipe are connected to it and the necessary steam is generated. The steam, together with the necessary air, is conveyed to the under side of the grates by means of pipes which pass down through the fire brick lining. These pipes, are, consequently, very hot and superheat the air and steam."

"The expansion tank serves the purpose of a small reservoir close to the engine, similar in purpose to a receiver over the throttle valve of a steam engine, reducing the speed of the gas from the scrubber at the moment the admission valve opens, and helping to take care of the inertia of the gas at the instant the inlet valve closes, in this way regulating to some extent the fluctuations of draft on the producer. This action also allows the gas to drop any water particles that it may be carrying over from the scrubber. Means are provided for draining out the water so deposited."

"When stopping the plant, the generator is shut off from the scrubber, and opened to the atmosphere. The natural draft keeps the fuel burning moderately, so that the producer can be put in operation again within a few minutes. The small amount of gas generated while the plant is standing idle, escapes through the smoke pipe."

"In first starting up the plant, a fire is kindled in the producer and is accelerated by a hand blower in the smaller sizes, and by a power blower driven by a small gasoline engine in the larger sizes. The products of combustion escape through a pipe leading to the atmosphere

until a trial at a test cock shows that suitable gas is being generated. The gas is then led through the scrubber and is allowed to escape to the atmos phere until the test cock placed at the engine shows suitable gas. As soonas suitable gas appears at the engine the blower is stopped and the engine is ready to start. The engine is given the first impulse by compressed air. The air is supplied from a small storage tank at a pressure of from 80 to 90 lbs. A small power air compressor is furnished to pump this air. One impulse of air is usually sufficient to start the en gine."

"The suction stroke of the engine creates the draft necessary to keep the producer in operation. It draws the air and steam through the bed of incandescent fuel in the producer. The air, steam, and coal are here broken up and the gases formed. The amount of air being limited, the combustion is incomplete and the result is the formation of carbon monoxide gas, free hydrogen gas from the steam, nitro-gen from the air, some carbon, dioxide, and other gases . These gases pass from the producer through the vaporizer, where they give up some of their sensible heat; then through the scrubber, where the gases are still further cooled and cleaned; and then to the expansion tank from which they are drawn into the engine during the suction stroke. It is to be noted that the entire system must be gas and air tight, as all the air must pass through the producer.

"When building a new fire, it requires about thirty minutes from the time of starting to obtain good gas. After shutting down over night, a period of ten minutes blowing by means of the fan is sufficient to insure

minutes blowing by means of the fan is sufficient to insure gas of proper quality for starting the engine."

"The most satisfactory fuel is anthracite pea coal. When using coal of suitable quality, the fuel consumption is guaranteed not to exceed 1 1/2 pounds per horsepower hour under full load, though actual practice has shown considerably more favorable results. Based on the above conservative estimate, with coal costing $4. per ton, the cost of fuel would be less than 1/3 cent per horsepower hour. In most localities suita ble coal can be bought at still lower figures, while even in places still further away from the anthracite fields the economy of the producer is very pronounced."

"Aside from the usual small amount of care required to keep the engine in order, the labor expended in operating the producer is limited to keeping the grates clean, or free from clinkers, removing the ash, and filling the hopper with coal. The actual time spent in these operations does not exceed 1 1/2 to 2 hours per day, according to the size of the plant."

"The general arrangement of the various parts of the plant is shown in the accompanying blue prints. In most cases it is convenient to have the gas plant in the immediate vicinity of the engine room, which is preferable. Where conditions require it, the producer and scrubber may be located at any distance up to 300 feet from the engine. Usually the increased cost of piping longer distances makes it desirable to ke ep the gas apparatus as close as possible to the engine."

"In the construction and erection of the producer every precaution has been taken to make it absolutely safe. The gas and smoke generate while starting the fire are carried away by a separate pipe into the outer atmosphere. The valves and pipe connections are so arranged as to prevent air entering the producer from the outside while the plant is idle. While the engine is in operation, only the required amount of gas regulated automatically by the amount of power taken from the engine, is generated. The pressure in any part of the apparatus, while the engine is running, is always below that of the atmosphere; consequently no leakage of gas to the outside is possible."

" No gas whatever is generated while the engine is idle. In case of imperfect joints, no gas can escape; on the contrary, the lower pressure in the producer and connections tends to draw the air into the apparatus, and the amount of air that might be admitted through a leaky valve or joint is not nearly enough to form an even apporximately explosive mixture. Should a more serious leak develop, the quality of the gas would become so poor as to compel the attendant to locate the cause and remedy it. The Otto Suction Producer is built by the Otto Gas Engine Works, at Philadelphia, Pa."

Up to the present time nothing much has been accomplished in the way of a suction regulator, with the exception, perhaps, of the Pintsch Regulator or Governor. "In this instance the engine on its charging stroke instead of drawing entirely from the producer, draws its charge in part from the governor, and the governor spring then compensates

this by drawing in a fresh charge from the producer, thus giving on the prod cer and through the apparatus a steady draft instead of the intermittent puff which would be made by the suction stroke of the engine piston. This steady suction gives a steady even draft through the fire, which is essential for the continuous formation of gas of a uniform quality. Another great benefit derived from this governor is the ability to run any number of engines from a single producer with a certainty of operation and without any loss in economy, by simply attaching a governor to each engine."

In the early part of our work we wrote to several firms to find out just what was on the market in the way of a regulator, and we enclose some of the replies:
We received the following from the Smith Gas Power Company of Lexington, Ohio.

"Dear Sirs:-

"Permit us to acknowledge receipt of your letter of Febr.15th. We are a little at a loss to under stand your reference,, as a suction gas pressure regulator is a piece of apparatus with which we have not come in contact. We presume by this that you refer to apparatus for equalizing the impulses produced by the engine cylinders, and distributing the same as a uniform draft on the producer. The only concern we know of who uses a distinct apparatus for this purpose is the Olds Gas Power Company of Lansing, Michigan, who manufacture the Pintsch Producers. This, as you undoubt edly know consists of a small gasometer mounted on springs. In our own apparatus this same effect is secured by the use of a very large scrubber so that there is ample capacity be-

tween the engine and producer proper to permit the sudden and prompt filling of the engine cylinders without causing any material depression in pressure below the average. We would be glad to hear from you further in regard to this matter, and give you any information we have in our possess ion when you explain a little more fully just the information you desire.

Awaiting your reply with interest, we are,

Yours very truly,, "

The following was received from the Otto Gas Engine Works, 33rd and Walnut Sts. Philadelphia, Pa.

"Dear Sir:-

Replying to yours of the 19th inst., we would say that we have found that a small gas tank the size of which is so that it will contain ten charges of gas for a given size cylinder, has been found entirely satisfactory. We have tried some other pressure regulating devices constructed on the lines of a gasometer but found that the results obtained did not justify the additional cost. By ten charges we mean ten times total cylinder volume.

Yours very truly,"

We have the following from late magazines;

From the "London Engineer" Page 309 Vol.99.

"It has been found, however, essential to a satis factory working that a small storage chamber should be insert ed between the gas engine and the gas producing plant to act as antifluctuator. Usually it is merely a closed vessel, and the gas therein acts as a buffer in minimising the intensity

and extending the period of the "pull" of the gas engine on the generating plant. The process of generation, regulation is efficiently tolerably under uniform conditions of rate of floor of the air and steam through the hot fuel, and such uniformity is secured to an adequate extent by means of the buffer of gas referred to."

"The Anti-Fluctuating chamber goes by various names according to the ideas of the makers of the plant, but perhaps "expansion chamber" "equalizer", and"gas box" are the commonest terms for it. In all cases it is a relatively small vessel, and in no way comparable in size with the gas holder of the older type of Dawson gas plant . Moreover, it is of simple construction as compared with the gasholder of the rising and failing bill type, being usually merely a close box of steel plate or cast iron."

"Messrs. Koerting have adopted a modification of the suction plant which appears to have disctinct advantages . Instead of depending on the direct pull of the gas engine when drawing in its charge, or equalizing the pull by means of an anti-fluctuating chamber, they use an exhausting fan, driven from the gas engine, on the outlet of the scrubber. Thus uniformity of rate of flow of the air and steam thru the fuel bed and of the gas through the scrubber is produced. The Gas World" of Febr.4, 1905 says:-

"As the Otto cycle is that most generally adopted for engines up to 100 H.P. it will be obvious that the flow of the gas drawn from the producer will be intermittent where a single engine is employed. As the suction stroke

occurs only once in every two revolutions or four strokes the entrance of air and steam is not continuous. But, if more than one engine or an engine having two cylinders or two cycle engines are applied, the generation of gas will be more uni-form, however, the flow of gas from the producer can be made more continuous by placing a vessel of moderate capacity in the system between the scrubber and the engine; this takes the place of the"Anti-Fluctuator" or " Gas Bag" usually fitted to engines fed from pressure producers."

"Where a number of gas engines are in-stalled or they are at considerable distance from the producer or where gas is needed for both power and fuel purposes or fuel purposes alone, we attach to our suction-gas producers or our patent pressure regulator system, by means of which an exhaust fan or a steam exhauster sucks gas from the generator and cleansing plant and forces it under pressure into a regulating gas receiver. By this system we furnish a PRODUCER SUPPLYING PRESSURE GAS WHILE THE GENERATOR IS UNDER SUCTION. The receiver is fitted with automatic valves connecting a return circulating system to the steam or fan exhauster. When the receiver is full this return valve opens automatical ly and the exhauster sucks from the gas receiver instead of from the gas producer generator, and circulates the gas back to the receiver."

"Gas is drawn from the producer gas genera tor only as required to keep the receiver in its top position and in accordance with the load. By means of this system a large gas holder is done away with, as the small gas re-

ceiver is automatically kept full of gas."

Having received these letters and carefully read our bibliography, we set about to follow out some suggestions offered by Prof. McFarland and a few ideas of our own which seemed feasible. Through the kindness of Prof. McFarland and the Cole Manufacturing Company we were enabled to set up our apparatus at their plant which is situated at Western Ave. and 32nd Street. The plant consists of a 60 H.P. Otto Gas engine and suction gas producer.

Our method of attack was to so arrange the apparatus, that the engine on its suction stroke would draw water up into a cylindrical steel tank. Since the fluid would tend to seek its own level again when the engine cylinder was open to the atmosphere, we determined that by restricting this backward flow we would get a regulation or steady pull on the producer due to the inflow of the gas to take the place of the receding water.

We first made a wooden tank of the following inside dimensions, 3 ft. 7" long 7" wide and 11" deep. It was made of material 1 1/8" thick, lap jointed with two bolts across each end. The inside was given two good coats of tar in order to make it water tight. In this tank we inverted the cylindrical steel tank above mentioned. This tank was 24" in diameter and 18" high. The bottom was entirely open and on top was riveted a 4" screw flange, connecting in this way with the producer. A hole was tapped in the regulator, into which we screwed a small pipe for our manometer connection. A manometer was also placed at the engine.

The wooden tank was made large in order to hold a quanity of water, and to facilitate putting in and taking out a series of wooden diaphragms. Our method of procedure was to make several of these at the shop and then go out to the plant and experiment with them. This saved running back and forth and enabled us to make a half day's ex perimenting at a time. (See blue prints for the different types of diaphragms.) Lugs were placed on each diaphragm and these were blocked up snugly against the regulator so there was no movements during the pulsations caused by the working of the apparatus.

In the diaphragm for our first experiment were placed three inlet valves 8" in diameter, and six outlet openings semi-circular in form, placed along the circum ference of the diaphragm, as shown in the blue print. The diameter of these openings was four inches.

The flap valves over the inlet openings were made of raw hide. We first operated the regulator with all the flap valves governing the inlet openings free, and with all the outlets open. This did not give the desired results, so we fastened down one of the flap valves, and weighted the other two to make them seat quickly and properly, and leaving the outlets opened as before, tried it again. We then opened up the flap valve we had fastened down, weighted it also, and this time closed three of the outlet openings. This seemed to work a little better owing to the fact that we had closed up some of the openings, so the diaphragm was taken out again and another outlet closed. The experiment

was carried on in this way until we had closed all the outlet openings. At this time our attention was called to the fact that we had made a mistake in using raw hide for the flap valves. We left the diaphragm in the water over one day, and on taking it out we found that the valves had soaked up, become flabby, and were swelled out of shape so that they would not seat properly. Having noticed this we may two more diaphragms on the same principle, but of a little different design.

As regards these we first experimented with one having two 8" inlet openings, both covered with perfectly blank galvanized iron flap valves. In our first test of this diaphragm there was a small hole 1" in diameter near the circumference, which was left open during the experiment. This hole was then closed up and another test,made, each apparently giving good results. The next test was made with a diaphragm having one opening 12" in diameter covered with a blank sheet iron flap valve. Tests similar to the pre ceding were made. Next the blank flap was removed and one with a central hole 1 1/2" in diameter put in its place. This one was next removed and one with a hole in its center 2" in diameter substituted. All seemed to give good results and the next day we made several runs of thirty minutes duration, with results as shown by accompanying log form. After this a diaphragm was used having four 6" holes and one 4" hole, giving approximately the same result.

As a last experiment we placed a diaphragm

Reading at Engine. 5/3/07

Valve Openings. No.	Size	Time	Vacuum	Regulation
0	0	10:00	2 7/8"	1/4"
		:05	2 1/2"	1/4"
		:10	3"	1/4"
		:15	3"	1/4"
		:20	2 3/4"	1/4"
		:25	3"	1/4"
		:30	3"	
2	8"	10:35	3"	5/8"
		:40	2 3/4"	5/8"
		:45	2 7/8"	9/16"
		:50	2 7/8"	9/16"
		:55	2 3/4"	9/16"
		11:00	2 3/4"	9/16"

Indications of water on outside of regulator were good, the water coming back but not reaching the original dead line.

1	12"	11:05	2 3/4"	9/15"
		:10	2 3/4	1/2"
2" hole in valve		:15	2 3/4"	9/16"
		:20	2 3/4"	9/16"
		:25	2 3/4"	1/2"
		:30	2 1/2"	1/2"

Indications on outisde of regulator about the same as before. Water is disturbed more on outside. The regulation on the outside of the regulator by actual measurement with a scale is 5/

Reading at Engine (Continued)

Valve Openings. No.	Size	Time	Vacuum	Regulation.
2	8"	11:40	2 3/4	9/16
		:45	2 1/2"	1/2"
		:50	2 1/2"	1/2"
		:55	2 3/4"	9/16"
		12:00	2 7/8"	1/2"
		:05	2 1/4"	7/16"

Indications on outside of regulator the same as before. The regulation seems steadier with this disphragm. The reading at 12:05 was taken with no load.

5/6/07

1	12"	9:10	2 7/8"	1/2"
		:15	3"	9/16"
		:20	2 7/8	9/16"
		:25	2 7/8	1/2"
		:30	2 7/8	1/2"
		:35	2 7/8	1/2"

Reading at Regulator

Valve Openings No.	Size	Time	Vacuum	Regulation.
0	0	10:00		
		:05		
		:10	This run was made without the	
		;15	regulator, readings being taken	
		:20	at the engine only.	
		:25		
		:30		
2	8"	10:35	3"	5/8"
		:40	3"	5/8"
		:45	2 3/4"	3/4"
		:50	2 3/4"	5/8"
		:55	2 3/4"	1/2"
		11:00	2 3/4"	1/2"
1	12"	11:05		1/2"
		:10		1/2"
		:15		1/2"
		:20		5/8"
		:25		5/8"
		:30		5/8"

Reading at Regulator (continued)

Valve Openings No..	Size	Time	Vacuum	Regulation
2	8"	11:40	3"	1/2"
		:45	2 7/8"	5/8"
		:50	2 1/2"	1/2"
		:55	3"	1/2"
		12:00	3"	5/8"
		:05	2 1/2"	3/8"
				5/6/07
1	12"	9:10	3"	5/8"
		:15	3"	5/8"
		:20	3"	5/8"
		:25	3"	5/8"
		:30	3"	5/8"
		:30	3"	5/8"
		:35	3"	5/8"

having a flap valve with central hole 2 1/2" in diameter in the steel tank. The flap valve was fastened to the diaphragm so it could not operate, therefore the water enetered and left through the 2 1/2" opening. On a 3" suction a 1" regulation was obtained. At one time during this experiment the gas became very poor, therefore the suction then increased to 6" and we were very much pleased to note that we had a regulation of approximately 4". From this we are led to believe that we have solved the problem, and that by placing a slide over one side of a small hole in the center of the disc through which the water must pass, a regulation for any given load can be made. This slide could be set for either full, half or quarter load, and could be adjusted by hand. The heavier the load the better the regulation.

All the diaphragms and valves are shown in the accompanying blue prints, also plan and elevation of the plant.

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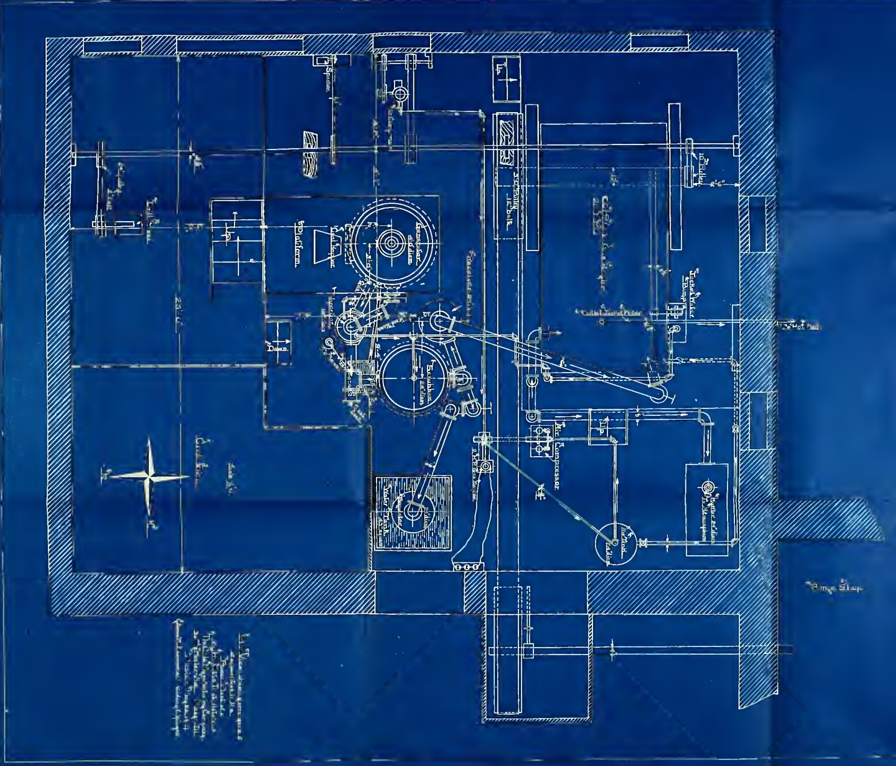
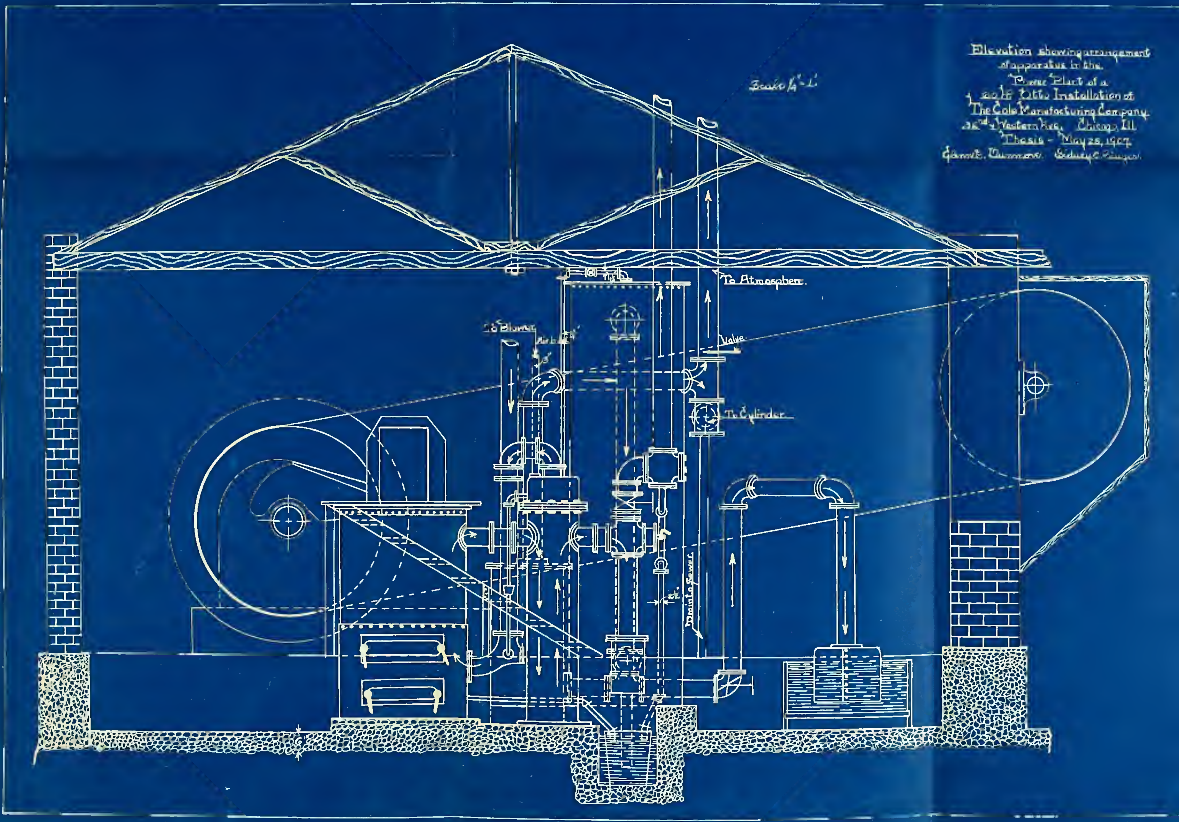
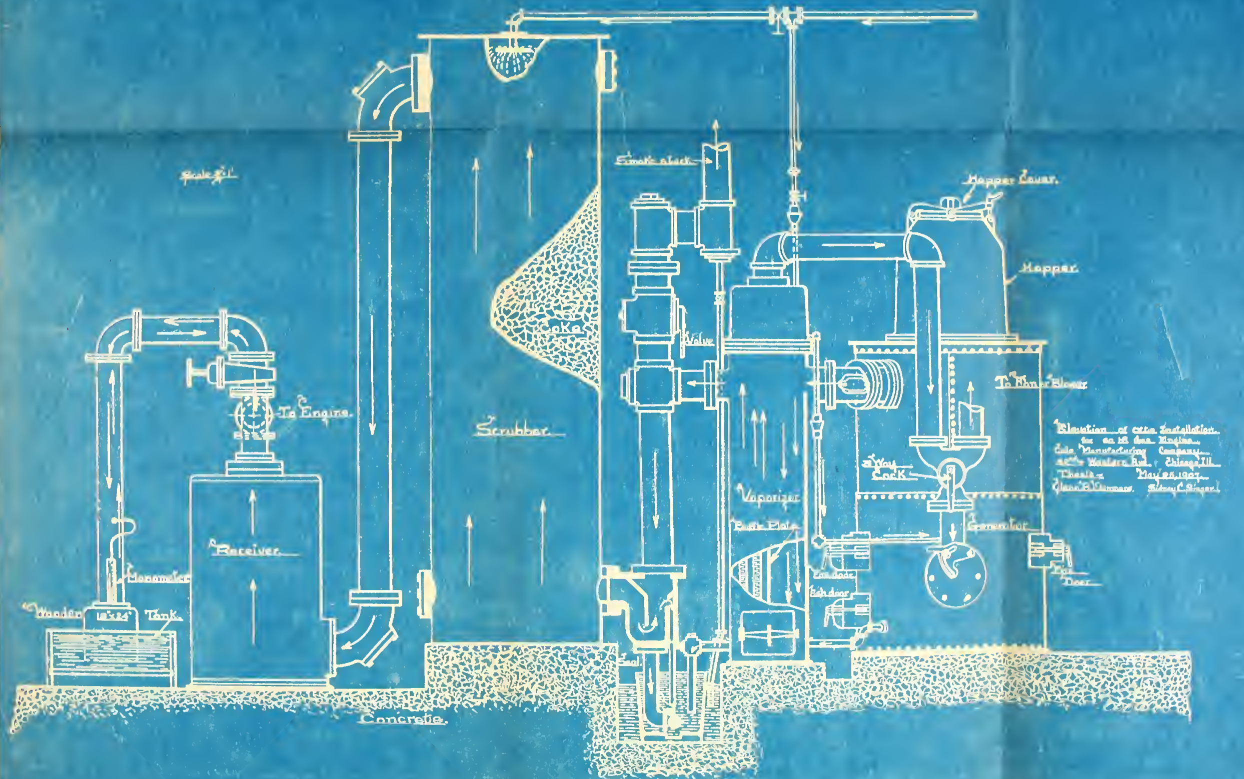

Air Compressor
Platform
Water Tank

Elevation of Installation


Elevation showing arrangement
of apparatus in the
Power Plant of a
200 HP Otto Installation of
The Cole Manufacturing Company.
Chicago, Ill.
Thesis - May 25, 1907.
To Atmosphere.
To Blower
Valve.
To Cylinder.

Diagrammatical Elevation of Installation.


Smoke stack
Hopper Cover.
Hopper
To Engine.
Scrubber
Coke
Valve
To Fan or Blower
Vaporizer
3 Way Cock
Generator
Receiver
Gasometer
Wooden
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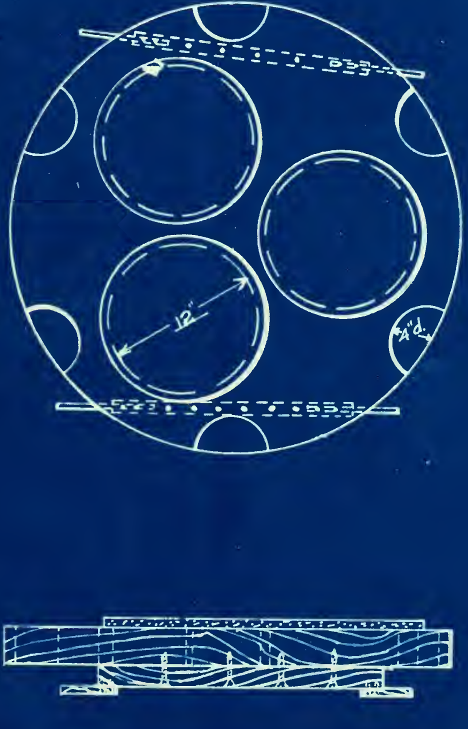

Rawhide type of Valve

Details of Regulator & Diaphragms.